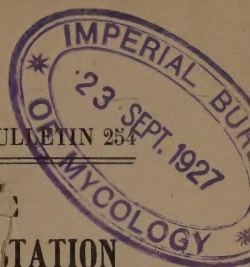


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A FRUIT MUMMY WHICH HARBORED THE BITTER ROT FUNGUS OVER WINTER AND BECAME THE SOURCE OF INFECTION OF THE TWO FRUITS BENEATH IT. MUMMIED FRUITS ARE USUALLY CAUSED BY BITTER ROT INFECTION OR DRYING UP OF SMALL FRUITS ON TWIGS KILLED BY FIREBLIGHT. THEY ARE THE COMMONEST MEANS OF HARBORING THE FUNGUS OVER WINTER IN VIRGINIA.

New Methods of Bitter Rot Control

BY R. H. HURT AND F. J. SCHNEIDERHAN

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New Methods of Bitter Rot Control

By R. H. HURT and F. J. SCHNEIDERHAN¹

INTRODUCTION

The data reported in this bulletin on new infection phenomena and methods of control of bitter rot resulted from experiments and observations made during the past three seasons at Crozet, in Albermarle County, and at Winchester, Frederick County, Virginia. They should serve as a basis for the control of bitter rot in all sections of the state.

Bitter rot (caused by the fungus, *Glomerella cingulata*) is recognized by southern apple growers as one of the most ruinous of the fungous diseases of apples. This is especially true in the Piedmont Section of Virginia, where Pippins, one of the most susceptible varieties, are grown on a large commercial scale. The disease is typically a hot weather trouble and occurs generally throughout the southern apple-producing states. In past years, especially in seasons of abundant summer rainfall and high temperatures, it has been a very serious disease in Virginia. Following the introduction of Bordeaux mixture in 1906 for bitter rot control, the growers used this spray material so effectively that bitter rot has become of less importance in commercial orchards in Virginia, and at present there is only an occasional orchard in which it exists as an important disease.

Although satisfactory control may be obtained with Bordeaux, considerable labor and expense are involved. The grower of the Piedmont Section commonly applies three Bordeaux sprays, and in seasons favorable to infection he may add one or two extra sprays. In wet seasons it is necessary to provide a continuous covering of fungicide from late June until harvest. We have attempted in our studies to find methods of control which would supplement spraying and obviate the necessity of so many applications of Bordeaux.

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DESCRIPTION OF THE DISEASE

The disease makes its first appearance usually during the first week of July, but it has been known to appear earlier, depending upon the kind of weather that prevails during May and June. The presence of the disease is first indicated by very small light brown spots beneath the skin, as shown in Figure 1. The spots are watery in appearance at first and after they reach a

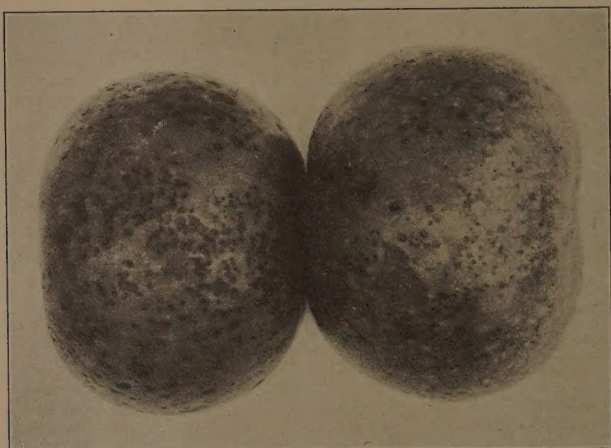


FIG. 1.—*The first appearance of bitter rot lesions on fruits of Early Harvest. These lesions are watery at first and comparatively few of them will develop large enough to produce spores.*

diameter of one-quarter to one-half inch, they become sunken because of the breaking down of the underlying tissue. If there are many lesions on one apple usually only a few of them will develop to appreciable size. In the Pippin variety the skin surrounding the rotten area usually shows a reddish discoloration. This is generally true of all yellow or green-skin varieties and may also be detected on red-skin varieties.

The apple disease with which bitter rot is often confused is black rot, caused by *Sphaeropsis malorum*. The two diseases differ in that the infected areas of bitter rot are watery at first and later become sunken, while there is no sinking of the area affected with black rot. After the spots of bitter rot have attained a diameter of one-quarter to one-half inch, acervuli, or masses of spores, begin to appear in concentric rings on the surface of the lesions, as shown in Fig. 2. The masses of spores which break through the skin give the spots a pinkish appearance at first, later becoming brown and finally black.



FIG. 2.—Large lesions of bitter rot on *Early Harvest* fruits, showing the concentric arrangement of acervuli or spore masses. These masses appearing white in the print are actually light pink.

SOURCES OF INFECTION

An apple severely infected by bitter rot usually drops, but frequently dries and persists on the tree as a mummied fruit. It has been known for a number of years that the bitter rot fungus may be carried over the winter, both in mummied fruits and in twigs and other small wood, but the relative importance of these different sources of infection has not been determined as definitely as is desired, although Alwood, in 1904, concluded that mummied fruits are the chief source of primary infection [Bulletin 142 of this Experiment Station].

This fungus, which passes the winter in a dormant condition in mummies or infected twigs, becomes active during the early part of June and beginning about the middle of June spores are produced during rains which cause the first infection. The first areas of infection are quite localized in the tree and occur in the form of a cone, at the apex of which is found the mummy on which the spores which caused the infection were produced. The conical infection area beneath a mummy results from the wash and drip of spores from this one point. The extent of the infection area depends somewhat upon the

velocity of the wind prevailing at the time. Mummied fruits on the ground play only a minor part in infection. It is possible, however, that some infection may occur on low hanging fruits, provided the spores are splashed upward from the mummies on the ground.

After the fruit has become infected bitter rot lesions appear and these produce spores in a few days and thus act as additional sources of infection. It is possible, therefore, that spores may come from infected fruits and from mummies at the same time, depending upon the length of the period during which the mummies produce spores. As the season advances, the infection in a tree becomes general and the original cone-shaped areas of infection largely disappear.

THE ROLE OF MUMMY REMOVAL IN BITTER ROT CONTROL

Investigations of the primary sources of infection were begun at Crozet in 1923 and at Winchester in 1924, and continued until 1926. These investigations were confined to three varieties, the Albemarle Pippin at Crozet and Early Harvest and Smokehouse at Winchester. A study of the various types of mummies and of their potential infecting possibilities was made in addition to experiments to determine the importance of mummy removal in the control of bitter rot. These experiments were made in conjunction with the regular spray program as followed in the orchards.

Mummies persisting on trees after leaf fall are of various types and originate from various causes. The commonest causes of mummies are bitter rot infected fruits, shrivelled small apples on twigs killed by fire blight, and other small apples drying upon limbs just after and during the June drop. Mummies formed early in the season by these various causes become completely shrivelled and small in size by fall, while mummies resulting from late bitter rot infection are of a larger size. An examination of 265 mummies removed from a Smokehouse tree which had been very severely infected by bitter rot enabled us to classify them into various groups with the percentage found in each group, as follows:

- Class 1.—Mummies with some pigment, uniformly wrinkled without sunken areas, average size, 25 mm. in longest dimension---20 per cent
- Class 2.—Mummies with some pigment, not uniformly wrinkled, not identifiable as bitter rot mummies, average size, 25 mm. ---15 per cent
- Class 3.—Mummies with some pigment, not uniformly wrinkled and identifiable as having resulted from bitter rot infection, average size, 28 mm. -----20 per cent
- Class 4.—Mummies without any pigment, grayish and carbonaceous, quite uniform in size without sunken areas and not identifiable as resulting from bitter rot infection, average size, 18 mm. -----40 per cent

Class 5.—Mummies without pigment, with definite sunken areas, quite lop-sided to flat and identifiable as having been caused by bitter rot infection, average size, 22 mm.----- 5 per cent

From the classification given above we infer that only 25 per cent of all of the mummies on these trees could be definitely identified as true bitter rot mummies. The remainder, or 75 per cent, resulted from other causes. The ones identified as true bitter rot mummies were usually flattened and lopsided, resulting usually from one large bitter rot lesion causing a sunken depression on one side of the apple and remaining so, more or less, even in the mummy form. It was found to be much easier to make a definite identification of a true bitter rot mummy in the class having some pigmentation than in the un-

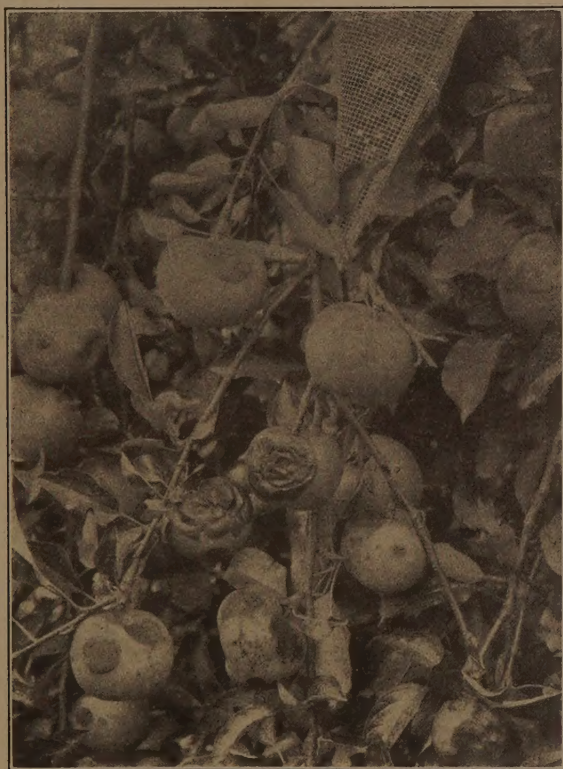


FIG. 3.—Methods of testing mummies for bitter rot infection. A wire cage containing bitter rot mummies and the infection resulting from the inoculum washed from it to the fruits of Northwestern Greening beneath.

pigmented type. This was due to the color contrast between the sunken lesion and the rest of the mummy.

It is noteworthy, that the large-sized bitter rot mummies which result from bitter rot infection late in the season are not nearly as important in carrying the fungus through the winter as the small nubbin type of the so-called fire blight mummy and others formed earlier in the season. This small type of mummy is capable of carrying the fungus through the winter and of producing spores the following season. The fire blight mummies and those resulting from apples shrivelling in June become very dark, hard, and small, compared to the mummies resulting from late bitter rot infection.

In determining the infecting possibilities of mummies we placed them in wire cages which were exposed in trees of bitter rot susceptible varieties. If the mummies harbor the fungus, an extensive infection zone, conical in shape, with the apex just beneath the mummy cage, results approximately at the time that bitter rot first appears under natural conditions. Figure 3 shows one of these cages containing mummies attached to a tree and the infection resulting from it.

The experiments to determine the importance of mummy removal in the control of bitter rot were made in 1924 and 1925 at Crozet, Virginia. During the early season of 1924, while the trees were still dormant, all mummies were removed from twenty Pippin trees which had been infested by bitter rot the year previous. Three trees were not demummified and were used as checks. Of these twenty trees, only five produced a full crop of apples. The trees were sprayed once with Bordeaux on July 17. The trees (check) from which the mummies had not been removed were sprayed on the same date with the same material. In the season of 1925 a block of seventy-six Pipin trees in the same orchard used in 1924 were demummified and eight trees were used as checks. Both of these blocks of trees were sprayed with Bordeaux on June 22 and August 6.

Table 1 shows the results obtained in bitter rot control by removing mummies in 1924 and 1925.

TABLE 1.—*The Effect of Mummy Removal on the Control of Bitter Rot in Pippin Trees of the Gentry Orchard, Crozet, Virginia, in 1924 and 1925. All Trees Received Bordeaux Mixture Spray July 17, 1924, and July 27 and August 6, 1925. Dates of Mummy Removal Were March 1, 1924, and March 4, 1925.*

Treatment	Year	No. of trees	Total fruits	No. of infected fruits	Infection percentage
Mummies removed -----	1924	5	4,911	236	4.8
	1925	76	102,000*	none	none
Mummies not removed--	1924	3	4,203	2,089	49.7
	1925	8	9,250	980	10.6

*Approximate number.

The value of mummy removal in the control of bitter rot is indicated by the data in Table 1, which show that in 1924 the percentage of infection in the demummified trees was only 4.8 per cent, compared with 49.7 per cent of infection in trees from which no mummies had been removed. If the infection in the check trees is rated as 100 per cent, then the percentage of infection in the demummified trees becomes 9.7 and the percentage of control achieved by removal of mummies is 90.3. In 1925 the demummified trees developed no bitter rot whatever, while the check trees developed 10.5 per cent of infection. If the data for the two years are combined and averaged, the check trees show an infection of 22.8 per cent, while that of the demummified trees is only 0.22 per cent. When the infection of the check trees is rated 100, the infection of the demummified trees becomes 0.96 per cent, and the percentage of control obtained by removal of mummies is 99.04. Since these experiments were carried on in a commercial orchard sprayed with regular orchard equipment, it is apparent that mummy removal when supplemented with a few sprays of Bordeaux is a valuable method of improving the effectiveness of bitter rot control.

METHODS OF REMOVING MUMMIES

Having seen the value of mummy removal as a supplementary practice in bitter rot control, the work of mummy removal from the trees can be appropriately discussed at this point. We have found a ten-foot pole to which a nail has been attached, and curved over the end, to be an effective implement to remove mummies. A ladder tall enough to reach all parts of the tree is also necessary. Most of the mummies can be knocked off with the pole, which should be light enough to be handled with one hand. The more persistent types can be removed by using the curved nail at the end of the pole as a hook.

Records of the time required to remove mummies from three large Smokehouse trees have been made. The average Pippin tree will not have nearly as many mummies as these Smokehouse trees because the latter had never been demummified and the infection in them was nearly 100 per cent during the three years previous to mummy removal.

The time required to remove the mummies from these heavily infested Smokehouse trees averaged $11\frac{1}{2}$ hours per tree. In an average bitter rot tree of Pippin in the Piedmont Section the time required would likely be less than half an hour.

One man can do the work, but not nearly as effectively as two. When two men do the work, one of them remains on the ground and directs the operations of the man in the tree, since the latter cannot always see the mummies without occasionally going to the ground to make an inspection. The man on

the ground also handles the ladder and picks up the mummies which should preferably be removed from the orchard and destroyed.

An important fact in mummy removal should be pointed out at this place. It is not necessary to remove mummies from every tree in an entire orchard. Only trees in which infection has occurred should be demummified. The average grower knows the trees in which bitter rot has been causing losses, but if he has not this information it is necessary to mark bitter rot trees during the growing season in order to identify them for mummy removal when the leaves are off the tree.

THE REMOVAL OF INFECTED FRUIT AS A FACTOR IN BITTER ROT CONTROL

Most of the secondary infection by bitter rot results from inoculum washed or splashed from infected fruits during rains. It seemed, therefore, that the removal of this source of infection would have some effect on the control of the disease. Experiments made in 1925 show that the removal of infected fruit is a very valuable practice and, as the data in Tables 3 and 4 indicate, it is a cheap and practical method of controlling bitter rot when supplemented by spraying.

A device known as the pole picker, consisting of a 15-foot pole to which this picker was attached, was used to remove the infected apples. Such a pole picker is an excellent implement for this purpose; it may be procured at local orchard supply stores for 50 cents. Where the trees are small, the operator may stand on the ground, but in large trees a ladder is necessary. The time required to remove infected fruits and the effect of this removal in conjunction with spraying on the control of bitter rot is shown by the data in Tables 2 and 3.

TABLE 2.—*Time Required to Remove Infected Fruits from Trees and the Results of This Removal on Bitter Rot Control When Practiced in Conjunction With One Bordeaux Mixture Spray Applied on July 17, in the Gentry Orchard, Crozet Virginia, 1924.*

Date	Trees used	Time required (minutes)	Ave. time in min. per tree	Infected fruits collected
July 2 -----	15	30	2.0	18
July 10 -----	15	32	2.0	15
July 18 -----	15	16	1.1	0
July 28 -----	15	17	1.2	15
August 7 -----	15	24	1.6	62
August 19 -----	15	18	1.2	35
August 26 -----	15	18	1.2	21
September 3 -----	15	17	1.1	5

Treatment	Total fruits	Number infected	Infection percentage
Trees sprayed—infected fruits not removed	4,203	2,089	49.7
Trees sprayed—infected fruits removed---	21,105	180	0.8

TABLE 3.—*Time Required to Remove Infected Fruits from Trees and the Results of This Removal on Bitter Rot Control When Practiced in Conjunction With Two Bordeaux Mixture Sprays Applied on June 27 and August 6, in the Gentry Orchard, Crozet, Virginia, 1925.*

Date	Trees used	Time required (minutes)	Ave. time per tree (minutes)	Infected fruits collected
July 1 -----	26	25	1.0	0
July 8 -----	26	30	1.2	48
July 15 -----	26	20	.8	0
July 25 -----	26	20	.8	1
August 3 -----	26	23	.9	0
August 10 -----	26	20	.8	0
August 17 -----	26	24	.9	4
August 27 -----	26	21	.8	0

Treatment	Total fruits	Number infected	Infection percentage
Trees sprayed—infected fruits removed---	53,900*	53	0.1
Trees sprayed—no fruits removed -----	9,250	980	10.5

Certain facts are apparent after examining the data given in Tables 2 and 3. In 1924 the average time required per tree for the season to remove infected fruits was approximately 7 minutes, and the total number of fruits removed was 180. The data for that year show that the removal of infected fruits in combination with one spray resulted in only 0.8 per cent of infection, while in trees from which no infected fruits were removed but which were also sprayed once, the infection percentage was 49.7. In 1925 the average time required to remove infected fruits per tree for the season was 11 minutes, the total number of fruits removed from the 26 trees was 53. The infection in

*Approximate number.

the trees from which the infected fruits had been removed was only 0.1 per cent, while in the checks the percentage was 10.5.

The average time to remove infected fruits from one tree during both seasons was nine minutes and the control of bitter rot from this practice in conjunction with the applications of the Bordeaux sprays was approximately 67 times as effective as the applications of the sprays only. We infer, therefore, that the cost of removing infected fruits is negligible compared to the results obtained.

In our experience of removing infected fruits early in the season, we found that these fruits in the trees enabled us to find the mummies which were the centers of infection. Removal of the mummies and infected fruits effectively stopped infection in that part of the tree. Where the number of mummies is small, this practice of removing both infected fruits and mummies in the same operation is advisable. Care must be taken to discover the first bitter rot infections on the fruit, or else, for obvious reasons, the disease will spread rapidly and the sprays will be less effective. Mummy eradication and removal of infected fruits are both supplementary to spraying for bitter rot. The local conditions in a particular orchard must be considered to determine the procedure to be followed. In some orchards there will be only a scattered infection in a few trees, and the removal of infected fruits in conjunction with spray applications would be advisable in such orchards. On the other hand, it is obvious that, in a tree carrying many mummies, it should be necessary to remove both mummies and infected fruits if control is to be expected. In such trees, the application of three or more Bordeaux sprays without mummy removal often fails to control the disease satisfactorily, particularly in years of high temperature and copious rainfall. For reasons that are apparent, it is impossible to make one recommendation that will cover the different local conditions. The grower must be the judge in this matter, realizing that both mummy eradication and the removal of infected fruits are valuable and practical supplements to spraying which enable the number of Bordeaux sprays to be greatly reduced.

TWIG INFECTION BY THE BITTER ROT FUNGUS

In an apple orchard situated about one-half mile from the Winchester Field Laboratory every crop of Smokehouse apples has been lost since 1922, on account of bitter rot. The grower applied the usual Bordeaux sprays for bitter rot but without success. Finally he called our attention to his failure in controlling the disease and suggested that we advise him about measures of control. Accordingly, we took charge of these three Smokehouse trees and early in the season of 1924 removed the mummies very carefully. A total of 265 mummies were removed, which is an excessive number for three trees. Three Bordeaux sprays for bitter rot were applied carefully and on time, but



FIG. 4.—*Bitter rot infection on Smokehouse fruits caused by the inoculum produced by infected twigs. All mummies had been removed and the trees were sprayed with Bordeaux mixture.*

our experience was similar to that of the grower, namely, a total loss of the fruit resulted. Figure 4 shows the nature of infection on these trees after they had been demummified and sprayed.

It was obvious that some source of infection other than mummies existed in these trees and it was demonstrated in 1925, after the trees had again been demummified that infection of twigs had occurred. On certain branches out beyond the rest and with no branches over them, we noted typical cone-shaped infection zones beneath small dead twigs. These twigs were not cankered but they had a scaly and roughened appearance. A number of such twigs were removed from the tree, sterilized externally, and used to make puncture inoculations by simply jabbing them into apples from a Northwestern Greening tree not infected. Thirty-six of such puncture inoculations were made on July 28. Infection occurred after six days and sporulation followed two days later. Of these thirty-six inoculations, 60 per cent resulted in infection. A second group of fifty puncture inoculations was made similarly to those above mentioned, with the result that 70 per cent resulted in infection. In addition to these puncture inoculations, twigs from the Smokehouse trees were placed

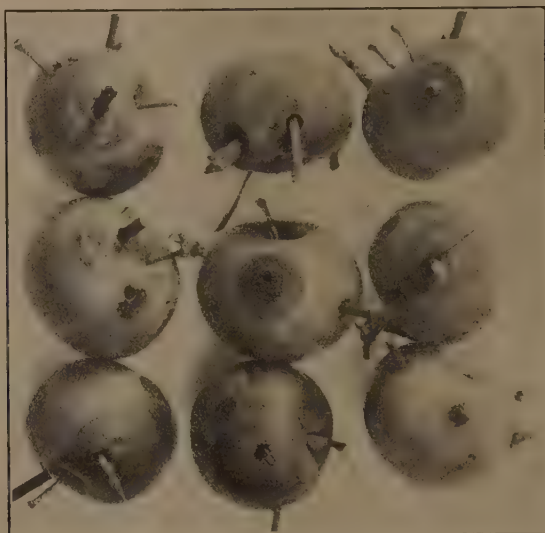


FIG. 5.—*Bitter rot infection resulting from puncture inoculations made with infected twigs from a Smokehouse tree which has lost every crop since 1922 because of this method of harboring the fungus, and in spite of mummy removal and spraying.*

on Early Harvest and Northwestern Greening apples in a moist chamber, with the result that infection followed six days later.

We infer from these results that the twigs harbored the fungus over-winter and provided a source of inoculum; a fact not hitherto known in this State. The Smokehouse variety is the only one in which twig infection by bitter rot has been observed in Virginia. This method of over-wintering of the fungus is probably not common in this State. The nature of the puncture inoculations and the infections resulting are shown in Figure 5.

BITTER ROT INFECTION FROM MUMMY STEMS

Another possible source of bitter rot infection is the stems of mummies which may persist in the trees after the mummies have been removed. About 15 per cent of the stems persist in the Smokehouse variety. In May, 1925, a wire cage containing stems of mummies was attached to an Early Harvest tree to determine whether or not such stems could be centers of infection. The fruit beneath this cage dropped prematurely and no infection was noted. On August 24 these mummy stems were removed from the cage, soaked in water for two hours and placed on Greening apples in a moist chamber. Innumerable bitter rot lesions appeared after ten days, while another lot of apples handled similarly but without using mummy stems showed no infection. This indicated that the bitter rot fungus remained alive in dried mummy stems after exposure in the cages for three months. From these observations we conclude that mummy stems persisting in apple trees after removal of the mummies may act as potential carriers of the fungus and as a source of infection.

TWO-YEAR SURVIVAL OF BITTER ROT FUNGUS IN MUMMIES

Observations made at both Winchester and Crozet, in 1926, show that the bitter rot fungus can live two years in mummified fruit and cause infection. A wire cage containing mummies produced in 1924 was attached to branches of Early Harvest and Northwestern Greening for the purpose of studying local infection. Bitter rot infection followed in a typical cone-shaped zone in 1925. The same mummies were left in the same trees during the winter of 1925 and 1926 and again a severe infection resulted in 1926. This infection was first noted in Early Harvest on June 28, and August 28 in Northwestern Greening.

Since these mummies had been attached to the trees for two years and twig infection by the fungus having been demonstrated in the Smokehouse variety, there was a possibility that twig infection was the source of the disease in the Early Harvest and Northwestern Greening in 1926. These mummies were, therefore, removed from the cage, soaked in water and placed in contact with Early Harvest fruit in a moist chamber. The infection shown in

Figure 6 resulted while the check fruit remained uninfected, thus showing that the infection noted in the trees resulted from inoculum produced by these two-year-old mummies.

No data on the length of time that bitter rot mummies persist in trees are available, as far as we know. If they persist for a period of two years, and this seems probable, it is apparent that two-year-old mummies would be potential carriers of the fungus.

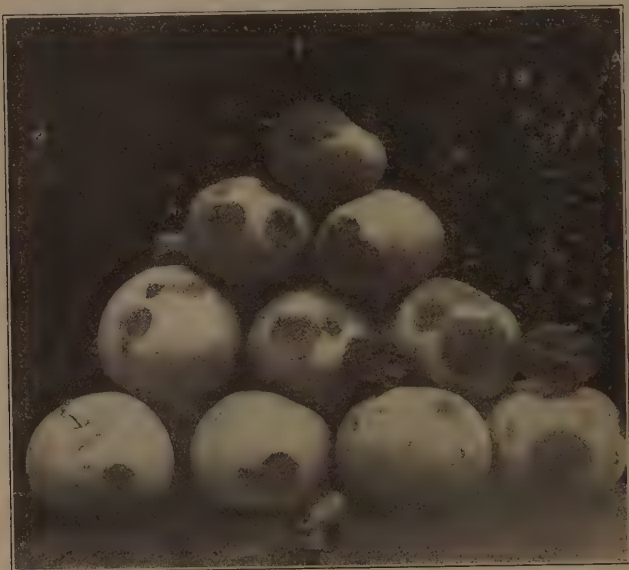


FIG. 6.—*Early harvest fruits infected by inoculum from 2-year-old bitter rot mummies placed in contact with them in a moist chamber.*

SPORE EMISSIONS FROM MUMMIES

We have seen from the previous discussions in this bulletin, that mummies are the chief agencies in harboring the bitter rot fungus over winter and, therefore, the centers of infection during the following season. The fungus remains dormant in the mummies until about the first week in June, when it becomes active and produces spores during periods of rain. No spores have ever been liberated without rainfall. The method of trapping spores of the bitter rot fungus consists in attaching a mummy cage to a large mouthed bottle in such a manner that the drip from the end of the cage is caught by the bottle. This bottle containing the drip is handled carefully so as not to

stir the contents, and by means of a pipette some of the drip is taken from the bottom of the bottle and examined with a microscope. The spores are easily detected in this manner.

Using this method, a record of bitter rot spore emissions has been kept at Winchester and Crozet during 1925 and 1926. These records are given in Tables 4 and 5, and show the extent of time during which mummies have produced spores in these two years.

TABLE 4.—*The Dates and Amounts of Spore Emissions from Bitter Rot Mummies, Together with the Rainfall in Inches Which Caused These Emissions, Winchester, Virginia, 1925.*

Date	Quantity of spores	Rainfall (inches)
June 14 -----	few	.15
June 18 -----	many	.20
June 23 -----	many	.48
June 24 -----	many	.76
July 4 -----	many	.33
July 15 -----	many	.70
July 21 -----	few	.90

TABLE 5.—*The Dates and Amounts of Spore Emissions from Bitter Rot Mummies, Together With the Rainfall Causing These Emissions, Crozet, Virginia, 1926.*

Date	Quantity of Spores	Rainfall (inches)
July 3 -----	few	.32
July 15 -----	few	.44
July 30 -----	many	.58
August 1 -----	many	.25
August 13 -----	many	.75
August 15 -----	many	.52
August 16 -----	medium	.58
August 17 -----	medium	1.05
August 19 -----	many	1.50
August 20 -----	many	.53
September 9 -----	few	.25
September 13 -----	few	.50

WEATHER IN RELATION TO BITTER ROT

The development of fungi which cause various plant diseases is affected by temperature and other weather factors. The apple scab fungus thrives best in cool, moist weather while the bitter rot fungus develops best in hot, humid weather.

A record showing the days on which weather conditions were favorable for bitter rot infection has been kept for three years at Crozet. In Table 6 these data for the three years are presented.

TABLE 6.—*Days Favorable for Bitter Rot Infection at Crozet, Virginia, During the Months June, July, and August of the Years 1923 to 1925, Inclusive.*

Year Month Date	Mean temperature	Rainfall (inches)	Date bitter rot appeared
1923—June 20-----	87	0.23	July 12
—June 23-----	87	0.12	
—June 24-----	87	0.19	
—July 4-----	81	0.13	
—July 8-----	78	0.12	
—July 14-----	80	1.94	
—July 24-----	71	0.35	
—July 28-----	80	2.08	
—August 3-----	81	0.27	
—August 4-----	81	0.24	
—August 27-----	74	0.23	
—August 28-----	75	3.25	
—August 29-----	77	0.24	
1924—June 15-----	70	0.96	June 25
—June 17-----	73	0.59	
—June 18-----	75	1.03	
—June 22-----	77	0.04	
—June 29-----	76	0.37	
—July 6-----	77	0.11	
—July 13-----	71	1.60	
—July 22-----	77	0.15	
—August 3-----	73	0.70	
—August 7-----	84	0.11	
—August 11-----	83	0.62	
—August 20-----	83	0.25	
—August 23-----	76	0.94	
1925—June 24-----	68	0.76	July 3
—June 27-----	78	0.85	
—July 6-----	81	0.95	
—July 8-----	84	0.68	
—July 9-----	81	0.39	
—July 31-----	71	0.80	
—August 4-----	76	0.20	
—August 9-----	78	0.75	
—August 10-----	81	0.19	
—August 11-----	81	0.55	
—August 12-----	71	0.24	
—August 21-----	68	0.11	

An analysis of the data in Table 6 shows that there were approximately 13 days in each of the three years that were favorable for bitter rot infection. The average interval between these favorable days in 1923 was 5.3, while in 1924 it was again 5.3, and in 1925 it was 4.8 days. The average interval between days favorable for bitter rot infection during the three years was 5.1 days. This frequent succession of favorable weather for bitter rot infection is one criterion for judging the necessity of keeping the fruits properly covered with spray material. As in the control of apple scab and brown rot of peaches, an important factor to remember is the prevention of initial infection by the fungus. Given an uncontrolled initial infection and favorable weather conditions, most of the fungus diseases of apples are difficult to control by spraying or other methods.

INOCULATION EXPERIMENTS WITH BITTER ROT

Bitter rot infection occurs only during rains and the period during which the trees are wet following rains. We have seen that rain is necessary not only to cause the fungus to produce spores, but also to scatter these spores and afford conditions for their germination without which there can be no infection. The length of the rainy period and that of tree wetness is important in determining the amount of infection by this disease.

Experiments to determine the length of time required for this fungus to establish itself in the fruit were made with such varieties as Pippin, King David, Early Harvest, Ben Davis, and Northwestern Greening. Most of these inoculation tests were made under laboratory conditions, but a few were made under field conditions.

The method used to determine the incubation period of the bitter rot fungus consisted of applying the spores to the apples either in the form of a heavy decoction or by rubbing the lesions of heavily infected fruits over the apples, and after periods of different length, during which the fungus was given the opportunity to establish itself, the inoculated apples were dipped in 4-5-50 Bordeaux mixture. This dipping in the fungicide killed the spores on the surface of the fruit and prevented further infection, while it would not stop the development of the disease in those apples that had already been infected.

Using the method of inoculation just described, we inoculated a total of about a thousand fruits of Ben Davis, King David, and Pippin. A slight infection resulted from an exposure period of 5 hours, but this infection was negligible. The fruits of these varieties were exposed only during a 5-hour period. Working with Early Harvest and Northwestern Greening a different procedure was followed, namely, the exposure after inoculation was for periods varying from 4 to 10 hours, both in the laboratory and in the field. The technique in the field inoculations consisted of inoculating in the manner

described above but enclosing the inoculated fruits in moist chambers made of quart-size ice cream cartons containing a wad of cotton soaked with water to maintain as far as possible a saturated atmosphere.

A total of 360 Early Harvest fruits was divided into groups of about 30 which were inoculated and exposed to infection for periods varying from 4 to 10 hours. The results show that no infection developed from an exposure of 4 hours; 1 per cent resulted in 5 hours; 6 per cent in 6 hours; 45 per cent in 7 hours; 69 per cent in 8 hours, and 95 per cent in 10 hours. All of the checks exposed to favorable conditions longer than 10 hours developed 100 per cent of infection. Inoculation experiments under field conditions with Early Harvest fruits resulted in a much smaller percentage of infection. There was no infection from a 6-hour exposure; 1 per cent in 7 hours; 3 per cent in 8 hours; 4 per cent in 9 hours, and 7 per cent in 10 hours. Indefinite exposure of field inoculations resulted eventually in 90 per cent of infection.

Using 500 Northwestern Greening fruits and dividing them into groups of 50 and exposing them to infection periods of 4 to 10 hours in moist chambers, the results were as follows: No infection resulted in 6 hours; 4.5 per cent in 7 hours; 41 per cent in 8 hours; 73 per cent in 10 hours. All checks exposed indefinitely became infected to the extent of 100 per cent. Under field conditions there was no infection after 6 hours of exposure; 1 per cent after 7 hours; 2 per cent after 8 hours, and 3 per cent after 10 hours. The checks exposed indefinitely developed only 5 per cent of bitter rot infection.

From this summary, we infer that infection does not occur under the most favorable conditions from an exposure of 4 hours; a slight infection results from a 5-hour exposure, and that a 10-hour exposure of Early Harvest fruits may result in 100 per cent of infection, while in Northwestern Greening only 73 per cent of infection resulted in that time. It would seem, therefore, that a minimum of 5 hours' exposure is necessary to first establish the fungus and that a 10-hour period would enable heavy infection to take place in Early Harvest and Northwestern Greening. A slight variation in the time required for infection is indicated by the data for these two varieties, and it is evident that field inoculations are not nearly as successful as those made in the laboratory where better conditions for infection can be provided.

HOW TO CONTROL BITTER ROT

The first essential in controlling bitter rot in any orchard is to have a thorough knowledge of the extent to which the disease occurs in the orchard. Such knowledge of local orchard conditions is fundamental to intelligent and successful control measures for this disease.

Mummy eradication and the removal of infected fruits are valuable measures of bitter rot control when supplemented by spraying with Bordeaux mixture. It is obvious that mummies need not be removed from trees which

were not infected previously. It is not practicable to remove mummies from every tree in an orchard, neither is it necessary, but in a severely infected tree the mummies should be removed; therefore, it is necessary to spot such trees in the orchard. In orchards having a scattered infection it is advisable to mark bitter rot infected trees for mummy removal in the dormant season.

The practice of removing fruits infected by bitter rot is an easy and practical method of control when properly supplemented by spray applications. This practice has the additional virtue of enabling the grower to discover unremoved mummies, since they are invariably near the fruits where the first infections are discovered. The first search for infected fruits should be made during the latter part of June and continued at weekly intervals until the second week in August. It is usually unnecessary to examine the entire orchard for infected fruits but only such portions as were infected in previous years. The infected fruits should be removed from the orchard and destroyed.

A thorough application of Bordeaux mixture should be made in all bitter rot orchards in the five- and seven-weeks' sprays. The formula of the Bordeaux should be 3-5-50.* Making these applications in conjunction with mummy eradication or removal of infected fruits or both will easily control bitter rot in Virginia.

SUMMARY

The fungus causing bitter rot of apples overwinters in fruit mummies resulting from bitter rot infection or drying up of small apples on twigs killed by fire blight or other causes. Overwintering in twigs was first observed in 1926 and only in the Smokehouse variety. Mummies are by far the most important means of harboring the fungus and they are seemingly the sole means in the Pippin variety.

Mummies have been found to harbor the fungus causing bitter rot for a period of two years and still act as sources of infection. It is probable that they may harbor the fungus for a longer period than two years.

The first infections by bitter rot have usually been found to occur in cone-shaped areas beneath a mummy. Secondary infection results from the dissemination of spores from infected fruits which are carried by the drip and splash of water during rains. No distinct cone-shaped areas occur in secondary infection.

The removal of mummies from bitter rot infected trees has been found to be a valuable and practical method of disease control when supplemented by spraying with Bordeaux mixture. Mummies are removed by means of a 10-foot pole with a curved nail driven in the end. With this implement the mummies are either knocked or pulled off the tree. The time required to re-

*NOTE.—Recent investigations in other states, particularly Ohio, show that smaller amounts of copper in Bordeaux mixture are very effective. The writers suggest that growers try Bordeaux of the 2-4-50 formula on a small scale.

move mummies from infested trees will vary greatly, according to the number of mummies, and no general rule or average can be stated at this time.

The removal of infected fruits at weekly intervals has also been found to be a valuable supplementary practice to Bordeaux spraying in the control of bitter rot. The infected fruits are removed by using a pole picker and the total time required to remove infected fruits from one tree per season is nine minutes, under conditions of average infection.

An analysis of weather data during the bitter rot seasons of 1923, 1924, and 1925 shows that there were approximately 13 days in each year favorable to bitter rot infection and that the average interval between these days was approximately 5 days.

Mummies were found to have produced spores for a total period of 37 days in 1925 and for a period of 72 days in 1926. Rain is necessary for the liberation of spores from mummies.

The minimum time required by the bitter rot fungus to establish itself after inoculation is about five hours. A 10-hour period of exposure was necessary to bring about heavy infection under the most favorable conditions in the laboratory. Under field conditions the time required would probably be longer.

The control of bitter rot is a comparatively easy matter and consists of the application of two Bordeaux mixture sprays, using the 3-5-50 formula in the five- and seven-weeks' sprays, supplemented, as local conditions warrant, by mummy eradication or removal of infected fruits or both.

